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The marine ecosystem services approach in a fisheries management perspective

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Abstract

This paper reviews the concepts of marine ecosystem services and their economic valuation in a European fisheries management perspective. We find that the concept is at best cumbersome for advising on how best to regulate fisheries even in an ecosystem context.

We propose that operational fisheries management must consider three different types of analysis, the yield of and the effect of fishing on the commercial species, the effects of fishing on habitats and non-commercial species and finally an overall analysis of the combined impact of all human activities on the marine ecosystem. We find that the concept of marine ecosystem services is not helpful for the two first mentioned types of analysis and that a cost-benefit analysis that is implied by the marine ecosystem services concept is inadequate for the third. We argue that the discussion needs to be divided into two: (1) finding the boundaries within which we accept impact on the marine ecosystem and (2) within these boundaries find the optimal fishing pressure, in mathematical terms replacing the unconstrained optimisation implied by the ecosystem services concept with an optimisation with constraints. The constraints are defined as to avoiding social unacceptable solutions.

1 Introduction

Humans benefits from a multitude of resources and processes that are supplied by ecosystems. Collectively, these benefits are described as ecosystem services [1]. This concept was developed to spread the idea that services provided by natural ecosystems can be economically and socially assessed. Costanza et al. [2] proposed to valuate all the ecosystem services and in this way establish a total overview on a common scale that will allow an estimate of the optimum benefits that human can get from the marine ecosystem. However, Fisher et al. [3] find the ecosystem service concept too imprecise for analytical use. Hughes et al. [4] argue that the long-standing approach to management of marine resources is based on a flawed conceptual model: the 'optimal' harvesting of targeted stocks in systems that are assumed to be reasonably stable and suggest that a new framework for developing the ecosystem-based approach to marine resource management is urgently needed.

Fish and fisheries are a vital source of food, employment, recreation, trade and economic well-being [5,6]. Fisheries have a particularly strong influence on some marine ecosystem components because of biomass removal, discarding of unintended bycatch, mechanical stress and damage by bottom contacting fishing gears [7-10].

Fisheries management is intended to support and improve human well-being. Fisheries management is multi-objective and at least four different considerations are relevant to fisheries management in the Northeast Atlantic Ocean. These objectives include: 1) Short-term and long-term economic yield to the fisheries; 2) Long-term Maximum Sustainable Yield (MSY) in weight from the species/stock; 3) Nature conservation; 4) Regional political considerations e.g. to maintain fishing as a viable industry in areas where alternative employment options are few.

Biological advice on fisheries management is often based on individual species/stock concerns and aims at MSY on a stock-by-stock basis. However, management considerations include a wider scope of concerns. All fishing extracts fish and shellfish from the marine ecosystem but also impact on other ecosystem components through by-catch and bottom impact. Operational fisheries management has the specific fishery as its object and the nature of the fishery needs to be explicitly considered. Therefore a general 'fishery' concept generating an impact on the entire ecosystem is rarely useful for operational management.

Achieving single- or multi-species MSY is not necessarily sufficient to assure all aspects of a healthy ecosystem and may need to be supplemented with measures to mitigate undesirable impacts on ecosystems. Reducing fishing mortality or changing selectivity should also reduce: (a) bycatch of non-target and sensitive species; (b) impacts on habitat and biodiversity, and (c) alterations that could possibly affect ecosystem functionality. Even though few multispecies and ecosystem models (or applications thereof) have yet met the ''standards'' expected for routine use, ecosystem models might at least help point in the right direction or tell us when we heading in the wrong one [11,12].

In Europe the EU Marine Strategy Framework Directive and the EU Biodiversity Strategy to 2020 require Member States to map and assess the state of ecosystems and their services in national territories in order to achieve 'good environmental status' [13-17]. Given the increasing environmental, economic, and social pressures on EU's marine ecosystem, a key challenge facing marine resource management agencies is to balance human uses and environmental protection in a way that sustains or increases societal wellbeing. Recent studies have attempted to connect ecological and social systems by cartographic mapping of potential anthropogenic cumulative pressures and impacts [18,19]. Ecological economics provide methods for estimating how people value various resources, which in turn should inform an appropriate assessment of trade-offs across different uses, environmental outcomes, and management scenarios [20].

Assigning monetary values to ecosystem services have two goals: first, to communicate the message that ecosystems are valuable to humans and thereby bringing conservation considerations to the political table and second, to use the values in market based regulations of human behaviour. In the context of operational fisheries management it is the latter that is central. Valuing services is an attempt to map the extent humans enjoy from a service onto a one-dimensional scale. This scale is chosen as the monetary value as money is a common concept across cultural borders.

The ecosystem services concept does not consider fisheries management tools and how these tools affect the status of the ecosystem. Fisheries management needs detailed information pertaining to the expected effects of decisions. Fisheries are specialized there is hardly a fleet that exploits an entire ecosystem; fleets are coastal or high seas and they fish the pelagic complex or the demersal communities; fisheries are not generalists.

The purpose of this paper is to evaluate the usefulness of the ecosystem services approach in operational fisheries management and as a background for this evaluation review the concepts of marine ecosystem services in a fisheries management perspective.

2 Classifying ecosystem services

The United Nations 2005 Millennium Ecosystem Assessment operates with four classes of marine ecosystem services [1,24]: Provisioning, Regulating, Supporting and Cultural services.

Provisioning and cultural services are human benefits while regulating and supporting services are preconditions for provisioning and cultural services. Provisioning services include provision of food, raw material for biochemicals and other goods that directly can improve human well-being. Cultural services are a mixed bag including *inter alia* provision of space for tourism and recreation but also the touristic value of fisheries. Furthermore, exploitation of the marine ecosystem has an ethical dimension as for all exploitation of nature. We require that human restrain its use of the marine ecosystem within ethical defined boundaries and we value when this is the case, e.g. depletion of the resources is unacceptable even when this is economic advantageous. Regulating and supporting services form a background system that needs to function; if not, the marine ecosystem would not provide the provisioning and cultural. Evaluating whether fishing may threat the functioning of the ecosystem either directly or indirectly may be through modelling the main characteristics of the ecosystem and its functioning. Such main characteristics are biodiversity and the resilience of the ecosystem. Further examples of modelling and ecosystem characteristics are discussed by Arkema and Shamrouri [21].

Marine ecosystem services can be grouped differently [3, 22, 23, 16]. Fisher et al. [3] find that there is no single best way of describing ecosystem services and notes that for fisheries management usage the classification should be linked to policy and management but also that for other usage different classifications may be more useful. Therefore, different groupings of ecosystem services may be needed depending on the context – different classifications are complimentary rather than competitive. However, in the following discussion we relate to the Millennium Ecosystem Assessment grouping.

3 The Concept of Valuating ecosystem services

The essence of natural resource management is making decisions about trade-offs [25]. One lesson from humankind's use of the oceans is that the services provided to us by the ecosystems are finite: often the demand for benefits from ocean resources exceeds their sustainable supply. There is a maximum amount of fish an ecosystem can supply for human consumption, for instance. Or there is a particular amount of space a wind farm can take up before it impacts local fisheries. This means that trade-offs/pay-offs need to be made among different services [26], including the requirements for sustainability of the ecosystem itself [12].

Arkema and Samhouri [21] point out that ecosystem services are defined by the demand by humans i.e. not by any characteristics of the biological system and a natural extension of this observation is to consider fisheries in the context of a cost-benefit analysis. The ecosystem services concept calls for a holistic analysis with a search for an overall optimum and a cost-benefit analysis therefore requires that we can assign monetary values and costs to fisheries impact on the ecosystem, to the cultural services impacted by fisheries as well as to net monetary profit from the landings. This suggests that we consider fisheries bio-economic models as a central tool in our analysis, e.g. FishRent [27]. However, such models typically describe closed systems and the output from fishing competes with or enhances provisioning of other products and services from the marine environment. An example is that land based food products influence the demand prices of fish. Also, a fisheries-based analysis of the well-being of a marine ecosystem will be only partial as the ecosystem is impacted by the combined effect of human activities among which fisheries are but one. However, for many marine ecosystems fisheries are considered to dominate human impact on the system, e.g. the North Sea [10].

3.1 The price of ecosystem services

As noted above analysis of trade-offs embedded in management decisions requires that the costs and benefits are brought on a comparable scale and that this scale is monetary valuation.

Although in practice it is associated with great difficulties to assign values to ecosystem services the theory is well developed [28]. The fundamental principle that is followed in valuating ecosystem services is to look for a direct market price for the service. If there is no market then people's willingness to pay is the general driving concept. Such indices may be satisfactory if the objective is to provide the ecosystem value as a communication tool. Where the intent is to use a market mechanism for regulating human behaviour and resource use, the price for non-market services is defined based on the desired ecosystem status and price setting becomes part of the regulatory measures e.g. through green taxes.

Provisioning services (e.g. landing of fish) has a clear market which sets a price for the product and this is also the case for some cultural services (e.g. tourism) but not for others (e.g. ethical issues, the legacy of nature). Ecosystem regulating and supporting services are generally not traded and priced on any market.

To compute the economic value of nonmarket goods/services, special valuation methods have been developed within environmental economics. The TEEB Synthesis Report [29] and Söderqvist and Hasselström [30] discuss how products/services are valued on the market and review valuing of non-market services presenting different valuation methods. Valuation methods can be divided into three main groups: a) revealed preferences (RP), b) stated preferences (SP), and c) other valuation methods.

Valuing ecosystem services can be analysed one by one in the analytical modelling framework. First of all it must be determined what impacts what (causality), and secondly to which magnitude. While both elements require empirical knowledge the latter one requires data either in terms of recorded data or estimated data by use of the valuation methods. The causality element is often the better described and in case of lack of recorded or estimated data the modelling framework is used in scenarios of *what-if* in which sequentially development of the scenarios indicates the robustness and resilience of the system.

We distinguish different categories of costs: costs directly associated with fishing, management costs and costs associated with ecosystem impact from fishing. In order to obtain the provisioning benefits (food) humans impact the marine ecosystem negatively, e.g. habitat deterioration from bottom contacting fishing gears. Obtaining food can be overdone and lead to overfishing, i.e. the long term yield decreases because of increased fishing. To some extent nature's self-regulation mitigates the effects of overfishing, but man is able to influence the system, however at some financial costs. Therefore, costs that refer directly to the management of the fish stocks must be distinguished from costs of other types of regulating services.

The fishermen incur some of the management costs while society impacts fishermen profit (and behaviour) by the way taxes and subsidies imposed on the fishery. Some overlap might occur between the types of costs that are "internal" to the fishery and "external" to the fishery [12].

The same kind of overlap is found with respect to cultural services and provisioning of fish in terms of catches by recreational fishermen. The catch of fish by recreational fishermen competes with commercial catches, while recreational aspects are considered as a cultural service.

Valuing supporting and regulating services requires that attention be paid to the possibility of double counting. Supporting and regulating services are components in the production of a 'fishable' fish. Therefore the value of those parts of the regulating and supporting services that are used for commercial fish production is included in the value of the fish on the market. This is equivalent to valuing a car based on its market price. The value of the car includes the value of the motor; if the motor is valued separately the value of the car should be reduced correspondingly.

4 Ecosystem services and fisheries management

In the following subsections we investigate each category of ecosystem services – provisioning, cultural, supporting and regulating services – and their role in fishery management and in particular if the ecosystem services concept is useful in operational fisheries management. An analysis of ecosystem services is by definition not complete in an operational fisheries management context as fisheries management also reflect on non-biological considerations such as distribution of wealth between stakeholders. Regional policies are distributional issues but some aspects i.e. the existence of fisheries dependent regions may be seen as a cultural service [31].

The ecosystem services concept works with that fishing can be considered to generate a general fishing pressure (fishing effort) on the ecosystem and Figure 1 indicates likely functional relationships between net benefits from ecosystem services and overall fishing effort. The upper curve in Figure 1, showing total human well-being, is found by aggregating vertically the benefit curves for each of the services. The condition for vertical aggregation to be valid is that the services are being public goods, i.e. individuals cannot be excluded from use and use of one individual does not reduce the availability of others. Provisional services are by far those best documented while valuation of other service categories is more questionable. The general form of these curves is discussed below for each service category.

The aggregate functional form for human benefits with increasing fishing pressure (upper curve in Figure 1) is determined by the weights (values) assigned to the provisional and cultural services versus the weights (values) assigned to supporting and regulating services. If high weights are given to the latter services the inevitable result is that fishing is not worthwhile. Fishing is not unique in this respect the same argument lead to banning all human activities.

There is a distinct risk of double counting the value of ecosystem services e.g. where supporting and regulating services have an opportunity cost and counted in the market, this cost is embodied in the value of provisioning services and should be accounted for separately. However, fishermen do not consider supporting and regulating services in their decision making (this is what the economists call an 'externality') while society must. Valuing supporting and regulating services separately is a way of taking the social costs of the use of these services into account.

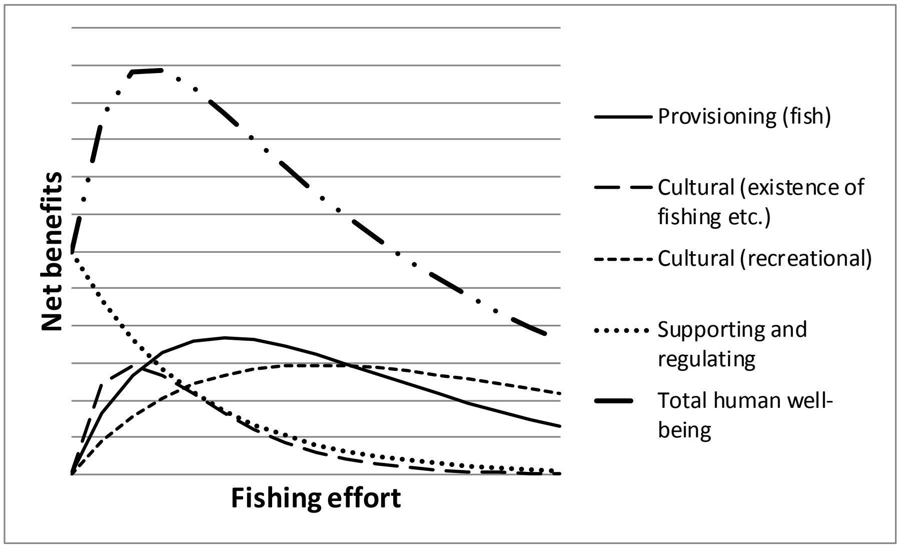

Figure 1. General functional relationships between net benefits from different categories of ecosystem services and fishing effort

4.1 Provisioning services in a fisheries management context

Provisioning services from a marine ecosystem include harvest of living organisms and material production. Provisional services are traditionally considered when analysing a fishery system [32] and include the benefits from fishing for food. However, fisheries management does not consider a complete enumeration of provisioning services from the marine ecosystem. There are harvests of marine organisms for other purposes than food, e.g. raw material for pharmaceutical compounds [33]. Chakraborty et al. [34] review anticancer drugs derived from marine organisms. This latter example illustrates that we need to be careful in defining the object for fishery management because these pharmaceuticals are mostly extracted from bacteria, tunicata, algae and other marine organisms that are not caught in traditional fisheries and therefore traditional fisheries management does not consider these provisioning services. In a fisheries management context we only consider those provisioning services that accrue from fishing with trawls, seines, gillnets, long lines and other traditional gears.

Net revenue from provisioning services is made up of gross revenue (yield) less harvesting costs. Gross revenue will increase with increased fishing activity until a point beyond which a reduction must be expected because the biological system reacts negatively to high fishing pressures. Fishing costs are assumed to increase with increasing effort, which means that when costs are subtracted from gross revenue a dome shaped benefit function appears as shown by the solid curve for provisioning in Figure 1 [35]. Management aims at a fishery that generates this optimum yield in accordance with the MSY principle. There are numerous fisheries models available that relate the expected yield either in the short or the long term with the fishing pressure [32] and there are data available to feed these models as commercial fisheries are generally well documented based on landing statistics, logbooks and species-specific abundance data from designated research vessel surveys.

Provisioning services include many issues that are fisheries management concerns but fisheries management will normally need information in much more detail than is built into the provisioning services concept, e.g. harvest by stock or species and harvest by fishery. Provisioning services do not invite such detailed description. The object for fisheries management is specialised fisheries and therefore must consider the provisioning services in relation to each individual types of fishery.

4.2 Cultural services

Cultural services include recreational, aesthetic, and spiritual benefits derived from nature. Coastal tourism is the fastest-growing sector of the global tourism industry, and is a major part of the economies of many small island states in developing nations. This sector provides recreational fisheries, scuba diving, and other nature-based tourism, for example whale watching. Moreover, the cultures and traditions of many coastal communities are intimately tied to the marine ecosystems. However, commercial fisheries do not affect many of these services. A major component of the cultural services is the existence of regions, which are fisheries dependent. It is necessary to distinguish commercial large-scale fishing[1] from small-scale commercial and recreational fishing because their contribution to the cultural services differs the touristic value of a small scale fishery differs distinctly from a full scale industrialized fishery.

Cultural services are typically linked to the coastal zone and management with emphasis on cultural services will focus on fleet structure in a spatial (coastal zone) approach.

The value of some cultural services will increase with increasing fishing (e.g. the existence of fishing communities) but cultural services also can impact the ecosystem negatively, e.g. ecotourism can stress components of the ecosystems and recreational fisheries extract fish in parallel with commercial fisheries and thus increase the stress on biodiversity. Therefore, in Figure 1 two likely benefit functions are shown for different components of cultural services, however both are dome-shaped. The models that are available for accounting for cultural services are mostly cost-benefit analysis; there is little available in terms of quantitative model. For recreational fishing data exist particularly for the data rich Baltic Sea area e.g. [36]. For other cultural services related to fisheries there are little data.

There are strong links between some cultural services and regulating and supporting services. An undisturbed ecosystem both may have recreational and aesthetic values. The coastal commercial fishery typically negatively impacts recreation in terms of leisure fishing and leisure sailing.

Cultural ecosystem services represent a gap in ecosystem service modelling [37]. There is great demand for tools to include such services in management analysis, but many categories of such services are intangible, there is yet no method of characterizing how ecosystem changes will affect cultural services [38]. Because many ecosystem services (co-)produce ‘cultural’ benefits, full characterization of services must address non-material values through methods from social sciences [39]. Clearly, work is required to convert existing socio-economic qualitative models into the framework of bio-economic models.

Fishery management rarely includes the value of cultural services in quantitative models but rather deal with these issues in a political process driven by stakeholders. There is a need for valuation of some of the cultural services in these discussions to rationalize the trade-offs that are required to reach an acceptable compromise among all stakeholders.

However, there are elements in the process typically ‘the legacy of nature’ that are soft arguments without an attached monetary value. The weight attached to such services is generally not agreed among stakeholders.

Fisheries management need to consider cultural services but also as was the case for the provisional services need to discuss this on a fishery-by-fishery basis because the cultural value differs between fisheries

[1] Large scale fishing boats are above 15 m in length and small scale fishing boats are below 15 m in length.

4.3 *Regulating and supporting services*

Fisheries impact the functioning of the marine ecosystem both through removal of target species, but also through non-commercial by-catch, and many fishing gears impact on the seafloor, i.e. all marine ecosystem services are affected. A marine ecosystem requires well-functioning regulating and supporting services including production of its pelagic (forage fish, phyto- and zoo-plankton) and the benthic (habitat) communities. These ecosystem services are functions that are prerequisites for the provisioning and cultural services. Fishing impacts the regulating and supporting services through affecting two processes food web dynamics and system resilience. An important element of the functioning of the system and its resilience is the *diversity of species* which for this reason often is discussed separately although this is neither a function nor a process.

Biological knowledge that is classified with regulating and supporting services can be essential in operational fisheries management. Examples include knowledge on spawning periods, larval dispersal with ocean currents and nursery zones which is fundamental information required for protecting stocks and designing a correct management policy under climate variability [40, 41]. According to Browman and Stergiou [40] work in fisheries science could move towards ecosystem based management by: (1) identifying and mapping the key faunistic components and the biodiversity 'hot spots' in the main ecosystems of the world's oceans; (2) describing the life cycles of these key components within the context of the Member-Vagrant Hypothesis framework described by in [42, 43]; (3) spatially mapping the life cycles of key species; and (4) identifying the special oceanographic features associated with the retention and nursery areas of these key components.

Fishing stresses the supporting (e.g. the food web, biodiversity) and the regulating (e.g. impairs the fish stocks ability to recovery from diseases) services. These negative effects lead to increased costs to society and hence lower net benefit that can be derived from the supporting and regulating system. Figure 1 therefore shows the value of the regulating and supporting services as monotonic decreasing with increasing fishing effort. In the subsequent analysis we detail the regulating and supporting services as food-web dynamics, resilience, habitat integrity and biodiversity. A key point is that the value for regulating and supporting services is associated with the crop through biodiversity while for provisioning services the production is the key feature that is valued.

However, the effects on the ecosystem from fishing differ by gear-type. Fishing with bottom contacting gears (trawls and dredges) affects production in the habitats while pelagic fishing gears affect marine mammals and sea birds. Operational fishing management therefore needs to consider differences and cannot work with a general 'fisheries pressure' concept.

4.3.1 Food web dynamics

Fishing reduces the diversity of the food web. Healthy ecosystems have diverse food webs necessary to achieve resilience of the system.

There are examples where fisheries management measures have been introduced to protect food-web dynamic, e.g. seasonal area closure around bird mountains to ensure food for chicks [44]. Another role of food-web considerations relevant for fishery management is the payoffs between species, e.g. can we fish more cod if herring is left alone. This latter mechanism is often discussed but rarely is the basis for management in marine systems. Commercial fish mostly belong to the higher trophic levels and the predation pressure on the lower trophic levels will decrease with increased fishing pressure. In general fisheries are not strongly affecting the food-web structure.

Food web models exist but are in some respects poorly developed (still under development) particular with respect to lower trophic levels. Data for some areas are good but there is uncertainty about the interdependence between the various trophic levels. Aggregate economic performance of the upper trophic levels is documented for the provisioning of food but it is expected that economic performance is impacted/changed with an explicit inclusion of the lower trophic levels.

As argued above the food-web is a part of the regulating services that are already valuated through the provisioning services. The food-web dynamics needs only to be considered by management as an additional cost where fishing negatively affects the food-web structure. Where management might want to use the existing structure to optimize yield at an ecosystem basis the value is included with the provisioning services.

4.3.2 Resilience

Resilience is about how systems (bio-physical and socio-economic) are able to respond (adapt) to a change or a shock while maintaining their characteristics or how quickly a system returns to its previous state following a shock [4]. Traditionally, bio-economic fisheries models assume that the system settles in a new equilibrium after a shorter or longer period and in particular returns to the former equilibrium – i.e. recovers - when the system is relieved of the fishing pressure. Empirical evidence shows examples of fish stocks that have recovered e.g. Atlanto-scandian herring [45] and stocks that have not e.g. the Grand Bank cod [46]. In general, there are few documented examples where an ecosystem has collapsed because of fishing and a regime shift has occurred, i.e. that the system was not resilient to the pressure. Where such regime shifts are suspected empirical evidence is difficult to establish as the available data are often restricted to the fish community. An example of a regime shift based on empirical evidence is presented in Tomczak et *al*. [47]. Reduced fishing effort and higher fish stocks is expected to increase the capability of the system to resist shocks but the increased robustness must be counted against expected short and medium term economic losses.

The resilience of an ecosystem is normally assumed as a given in fishery management i.e. that if fishing effort is reduced the system will return to its previous state. As with the food-web discussion the costs that need to be considered in valuating ecosystem services in the context of fishery management is the risk of a regime shift caused by fishing.

4.3.3 Biodiversity

Biodiversity is a feature of an ecosystem’s regulating and supporting services in the way as is resilience. High species diversity assures a robust ecosystem, an ecosystem that is resilient to pressure from e.g. fisheries [48]. The fishing activity reduces the species diversity of the ecosystem. Not only target species are affected but because fishing gears are not fully selective, non-target fish species, invertebrates, sea birds, turtles, marine mammals e.g. [49, 50] and undersized target fish are caught as by-catch e.g. [51]. These by-catches are discarded and the majority of the discarded fish and animals do not survive. Studies of by-catch and discard do not show a clear picture of the ecosystem effects [52].

A special aspect of biodiversity is the protection of vulnerable and threatened species. These may be taken as by-catches. These species will rarely affect the functioning of the ecosystem significantly but are protected based on ethical considerations the need not to cause the extinction of species. This is not part of the regulating and supporting services but rather a cultural service. There are examples where rareness in itself can be the basis for a provisioning service, e.g. whale watching.

Fisheries management needs to consider the effects on biodiversity and fisheries impact on threatened species. The regulations need to be specific to the threat and rarely if ever the broad brush of ecosystem services are useful.

4.3.4 Habitat Integrity

The biological processes in the sea bottom are part of the supporting and regulating services but the sea bottom fauna can also be the source of provisioning services e.g. mussels, scallops, sand and gravel. Furthermore, the sea bottom can provide cultural services in the form of marine reserves e.g. coral reefs. Healthy habitats are preconditions for fish production but are also affected by the fisheries themselves. Therefore an analysis of the ecosystem services in a fisheries management context needs to investigate this ecosystem component separately.

Certain habitats constitute important spawning and nursery areas that would call for specific protection.

Fishing with bottom contacting gears impacts the sea bed and consequently impact the entire ecosystem. The impact on living and non-living resources on and in the sea bed tends to jeopardize the food web, the diversity of species and the resilience of the ecosystem.

It is quite intuitive that trawl fishing may contribute to reduction of biodiversity (e.g. fewer old individuals and reduced productivity of slow growing species), even though, in general, it does not reduce ecosystem functions of a given area, if habitats and functional benthic species are not totally removed or destroyed [53]. Therefore, it is assumed that the original community has the possibility of recovering after the trawling disturbance, if fishing is banned for a sufficient time interval providing sufficient recruitment areas exists. This is the basic principle that rules the no-fishing periods adopted by European countries.

Fisheries management needs to consider fisheries impact on the habitats but in terms of valuation it is only the costs external to the fisheries (e.g. reduction of certain mussels without impact on the fish production) that are of interests. These are of the non-market nature and very difficult to valuate as discussed in section 3. There are human activities that have costs borne by the fisheries e.g. sand and gravel extraction and where the sea is used as a dump.

Marine reserves are often introduced to protect biodiversity, food webs and resilience but may also be introduced in their own right as a “national park” as a cultural services. Other human activities will dictate that certain areas are reserved for this purpose and *de facto* function as marine reserves or areas with restricted human activities. For example the use of Marine Protected Areas (Natura 2000) and marine spatial planning related to wind farms e.g. [54-56]. This discussion is at the centre of the discussions on Marine Spatial Planning [57-59], however, this is not further explored in this paper.

Marine reserves are generally considered to have negative economic impacts on the fishery; however, if provision of other services than fish (e.g. cultural service whale watching) is included, habitat protection may come out economically positive. Fock *et al*. [60] evaluated four scenarios against the EU policy goals and showed that two measures combined in an integrative assessment, i.e. effort reduction to MSY and areal closures, are likely to meet requirements from 3 environmental policies. Some data is available with regards the direct effects of fishing at least for the Baltic Sea. The importance of habitats for the marine ecosystem is in many areas documented [e.g. 61] but not with respect to the economic repercussions.

Bio-economic studies carried out for studying the effects from protecting habitats (protected areas or marine reserves) are mainly directed towards investigations of possible increases in the provision of fish only while non-commercial species living in those areas are normally disregarded. Fisheries models used for fisheries management purposes mostly do not account for this destruction of the sea bed.

5 Discussion

We consider two purposes of the ecosystem services concept: as a conceptual cost-benefit analysis at the ecosystem level that might be useful for communication of the consequences of ecosystem impact by humans and the possible use of ecosystem services and their value in operational fisheries management. The first of these belongs in class of advocacy biology while we investigate the possible use of the concept for operational analysis in this paper.

The first use focuses on the ecosystem at large and fisheries are but one sector among many human activities that affect the marine ecosystem. Taking this approach in a discussion of fisheries impact is ignoring the influence of other sectors and many lead to ineffective conclusions through regulating a sector with only minor impact leaving sectors with large scale impact unaffected. Beyond raising awareness the concept is not sufficiently fine-tuned for an informed analysis in a specific case.

In operational fishery management the valuation part that is embedded in the ecosystem services concept invites the use of ‘green’ taxes, as a management tool. Such a tax on fishing effort could regulate the fishing effort and can in principle achieve MSY fishing. Society will recover the costs of ecosystem use in the form of a fee or subsidise fisheries that benefit the cultural values of the fisheries. However, this is a political process in scientific veils. The principle behind the valuation ‘willingness-to-pay’ is a vote on the importance attached the various ecosystem components. Furthermore, the pay-off among different impacts depends on interest rate applied in the analysis as this defines the time horizon that is relevant for analysing the biological impact. The interest rates that in western countries in the 1970s and that of to-day are quite different and we do not consider that the objectives in terms of the status of the marine ecosystem should differ between the two periods. We argue that there are impacts that are unacceptable even if these might be economical rationale. This does not exclude the use of ‘green taxes’ as a management tool only that we cannot find the appropriate level of such taxes through a scientific analysis unless we are told what the desired outcome should be.

Fisheries management considers individual fisheries and sharing of stocks between fisheries. For this reason fisheries management must use a detailed breakdown typically at the stock or species level and should consider fisheries individually. This breakdown is also necessary in the valuation process because of price differences between products, e.g. a kg sole fetch about ten times the price of a kg of plaice and the cost structure differs between fisheries e.g. oil and capital costs are much higher for trawlers than for gillnetters. Hence, a bio-economic analysis useful in operational fishery management must have the fishery as its study objective and the provisioning services at the ecosystem level is not a useful concept.

Individual fisheries differ in their impacts on the ecosystem. Operational fisheries management needs to distinguish between small scale and industrialized fleets, management needs to distinguish between passive and active gears, between pelagic and bottom contacting gears. Gillnets and long-lines which are passive gears are a greater threat to sea birds than active gears while gears must have bottom contact to be a direct threat to sea bottom habitats.

The analysis presented above suggests that operational fisheries management as background needs three analyses. Finding the MSY target may be based on a bio-economic analysis that focuses specifically on the fishery and its target species. Avoiding specific threats to habitats and the non-commercial by-catch including threatened species may require a separate analysis. Finally and third, a wider analysis that considers the combined impact from all human activities on the marine ecosystem among which are the fishery may inform if the total pressure on the ecosystem is unacceptable. The first analysis will respond to the MSY requirement at the level of the single stock or if broadened the commercial fish stocks combined exploited by the fishery while the second and third analysis answer the question if the human activities combined threatened the functioning of the marine ecosystem or elements that we consider important.

The ecosystem services concept may be useful at the conceptual but not at the specific level where the concept degenerate to a consideration of the usual set of parameters i.e. effects on target species and commercial by-catch, identification on non-commercial by-catches and the effects on these and abiotic effects. Monetary valuing of regulating and supporting services are not relevant first because the provisioning and some cultural services already include some of these costs and secondly because we do not accept the implied payoffs between impacts. Even if it is economic rationale to extinct a species this is not acceptable. Analysis of distributional aspects to discuss equity concerns require an estimation of who receives the service benefits, while sustainability and stewardship analyses focus on the intertemporal distribution of those services. As with the regulating and supporting services rather than valuating cultural and ethical services such considerations may place constraints on acceptable decisions.

It is evident that human activities impact ecosystems and a balance between human use and nature protection must be found. This balance cannot be scientifically based as there is no consensus at society level about the values involved and therefore we do not find monetary valuation useful in operational management. Also, we find that some actions that may be rationale economical are inappropriate on ethical grounds, e.g. deliberate extinction of species. Environmental concerns and human use of the ecosystem are independent dimensions and the balance is achieved through a political process. It is the role of scientists to inform such a debate.

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